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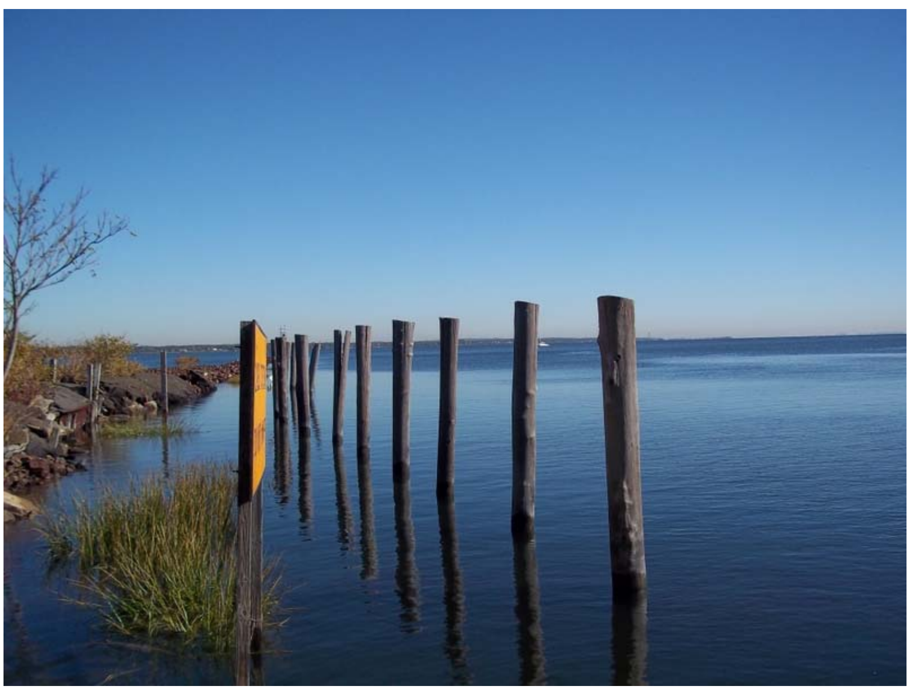
Final Work Plan
Currents and Sediment Dynamics Studies for the Raritan Bay Slag Superfund Site



Prepared For:
CDM Federal Programs Corporation
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Chantilly, VA 20151

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November 2010

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1.0 INTRODUCTION

Approximately 40 years ago, slag from a secondary lead smelter was used to construct a seawall along Raritan Bay and a jetty on the western side of the Cheesequake Creek Inlet (CDM, 2010). The site is now known as the Raritan Bay Slag Superfund Site (the Site), and is located in Old Bridge, Laurence Harbor, and Sayreville, New Jersey (Figure 1). In the decades since construction of the seawall and jetty, heavy metals, including lead, arsenic, chromium, antimony, and copper have weathered (particulate and dissolved) from the slag and been transported to adjacent areas of Raritan Bay (CDM, 2010). Existing data indicate the presence of heavy metals contamination in both sediments and surface waters (CDM, 2010). In an effort to further understand the fate and transport of these contaminants, Woods Hole Group has been contracted by Camp Dresser and McKee (CDM) to characterize the physical processes that dominate the area.

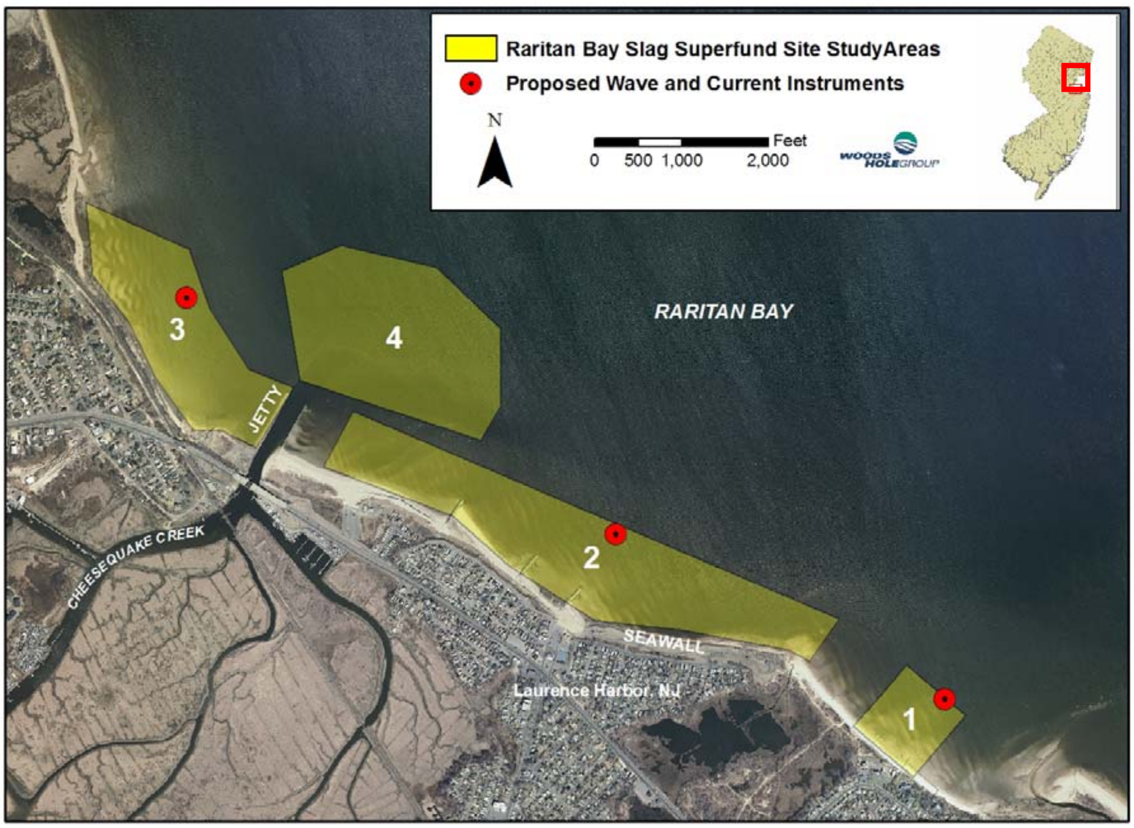

Figure 1. Basemap of the study area.

Based on the concentration of the primary heavy metal contaminant, lead, in sediments and the evidence of migration, there is a need to understand the processes contributing to the sediment/contaminant transport. The work outlined in this Work Plan is designed to provide the technical basis for addressing these issues. Specifically, Woods Hole Group will provide CDM with information required to inform the conceptual site model (CSM) in the Remedial Investigation (RI). The approach of this Work Plan includes a combination of field measurements and analysis techniques to: (1) better understand/explain the present distribution of lead in sediments; and (2) to provide a basis for predicting the future distribution. Woods Hole Group anticipates the results will also be used to identify areas (e.g., depositional areas) where additional sampling may be warranted. The approach is based on experience on other Superfund Sites and critical coastal sites, with a sound understanding of the type of information required to support the RI/FS process, inclusive of CSM development, delineation of the nature and extent of contamination, risk assessments, and evaluation of remedies.

The CDM RFP (CDM, 2010) outlined two (2) primary objectives, which will be accomplished by this Work Plan:

- **Objective 1: Characterize Hydrodynamics and Sediment Dynamics in Four Study Areas (as shown in Figure 1)**

- **Objective 2: Collect Field Data for an Exchange Study**

In this Work Plan, Woods Hole Group offers a technical approach to achieve both objectives, which are organized according to the following four (4) tasks.

Task 1. Planning and Mobilization
Task 1 includes the development of this Work Plan to more specifically detail the scope of work that will be performed to accomplish Objectives 1 and 2. Task 1 also requires WHG to develop a specific Accident Prevention Plan (APP) Addendum to the CDM APP in place for the Site. As an attachment to the WHG APP Addendum, a dive safety plan will be developed by subcontractor RanDive.

Task 2. Field Study
The Woods Hole Group (WHG) will be performing a field study to characterize the nearshore current, wave, and sediment dynamics at the Site. This study will focus on four sections of the Raritan Bay Slag Superfund Site, which have been identified as Areas 1, 2, 3, and 4 in Figure 1. The shoreline of the Raritan Bay Slag Superfund Site is fronted by sandy beaches and engineered structures such as seawalls, groins, and jetties. A major physiographic feature of the study area is the Cheesequake Creek Inlet, located between Areas 2 and 3; the construction material of the inlet's western jetty is a known source of contamination at the site. To this end, WHG will quantify the tidal exchange through Cheesequake Creek Inlet, in addition to characterizing the littoral wave and current regime along the shoreline. Current and wave data will be quantified using a series of different acoustic Doppler current meters and methods of measurement.

This work plan has been developed to successfully complete this field study and respond to the desired objectives. The work plan consists of three primary operations:

- Installation of a horizontal mounted acoustic Doppler current profiler (H-ADCP) in the Cheesequake Creek Inlet (*Objective 2*)

- 12.5-hour tidal cycle current survey using a vessel mounted ADCP, along with water column profiles of turbidity and other pertinent parameters (*Objectives 1 & 2*)
- Installation of bottom mounted acoustic Doppler current meters at two locations and a bottom mounted wave/current acoustic Doppler meter at a two other locations (*Objective 1*)

All aspects of the field study will be performed in accordance with the APP Addendum WHG, 2010 – in progress), and with WHG procedures for quality control and assurance.

Task 3. Quantitative Process Characterization
A quantitative characterization of the Site's coastal processes will be performed in Task 3. This will include, but not be limited to a characterization of the spatial distribution of nearshore wave energy, offshore wave energy, nearshore circulation and wave-induced currents, longshore sediment transport, and sediment flux. The scope of this task will focus on two items: 1) presentation and analysis of the field study data (Task2), and 2) analysis of existing data and models in Raritan Bay. The evaluation will help address the key questions posed in the RFP (namely to truly provide "explanations of the distributions of contaminated sediments and a prediction of a future distribution of contaminated sediments" as stated under Objective 1). The quantitative process characterization will provide a tool to determine the extent to which contaminated sediments may be transported father along the shoreline, and also to understand the conditions that may contribute to reversals of transport. This information will better inform the Conceptual Site Model (CSM), and help understand future potential risk.

Task 4. Reporting
The results of the Task 2 Field Study and Task 3 Quantitative Process Characterization will be reported as part of Task 4. The report will provide descriptions and plots of the field study data, as well as interpretations of these data with respect to coastal processes.

2.0 PLANNING AND MOBILIZATION (TASK 1)

A major component for the successful completion of the field study is the review of existing data collected by CDM, the EPA and other researchers. These data will familiarize WHG with the Raritan Bay Slag Superfund Site, and facilitate the selection of the most appropriate methods for data collection. Before any field work is initiated, along with this Work Plan, a project specific Accident Prevention Plan (APP) Addendum will be completed. Additionally, since WHG plans to contract installation services to a commercial diving outfit, a project specific Dive Plan will be completed and included as an Attachment to the APP.

2.1 APP ADDENDUM AND SAFETY CREDENTIALS

The WHG corporate safety officer will develop an APP that identifies potential physical, chemical and environmental safety hazards, and outlines the pertinent safety equipment and emergency contact information necessary for the safe completion of this project. The APP will be included as an Addendum to the client's Raritan Bay Slag Superfund Site APP.

Woods Hole Group is committed to providing its employees and subcontractors with a safe workplace, both in the office and in the field. Field engineers, scientists, and technicians possess current OSHA 40-Hour HAZWOPER, and Red Cross First-Aid/CPR certifications.

The WHG Field Leader will call a safety meeting before starting work each day to discuss the day's operations, schedule, and identify any safety hazards.

2.2 DIVE PLAN

The instrument deployments and recoveries described in Tasks 2-1 and 2-3 will be performed by WHG field engineers and subcontractor Randive of Perth Amboy, NJ. Woods Hole Group will supervise Randive activities. Randive was selected as the WHG diving subcontractor due to their proximity to the site, as well as their expertise and experience in working with oceanographic equipment. Randive will provide a vessel to serve as the offshore work platform, and a 4-man USACE-compliant dive team to deploy, secure, and recover the instrument platforms.

Randive will develop a project specific dive plan, which will describe diver tasks, certifications, and safety protocols. The dive plan will be submitted as an Attachment to the APP.

2.3 SITE RECONNAISSANCE

Following development of the Work Plan and APP Addendum, WHG will conduct a one-day reconnaissance trip to familiarize themselves for the data collection efforts and site characterization. WHG feels this is necessary to ensure that field efforts run efficiently and that the interpretation is performed by personnel who are innately familiar with the environment.

2.4 MOBILIZATION

Mobilization for all field activities will take place at the WHG Falmouth office. Activities are to include, but not be limited to:

- procurement, maintenance, testing, and preparation for all instruments
- procurement of instrument batteries
- fabrication of instrument mounting brackets and platforms
- preparation of safety equipment
- familiarization with work plan
- development of work plan schedule and travel plans
- coordination with subcontractors

On-site field mobilization and demobilization efforts will take place at the Browns Point Marine Service marina in Laurence Harbor, NJ. The marina location inside of the Cheesequake Inlet is ideal due to the proximity to the Site. The nearest boat ramp is located at Zuback's Marina, which is directly across the creek from Brown's Point Marine Service.

Browns Point Marine Service
1703 State Route 35
Laurence Harbor, NJ 08879
(732) 264-7176

2.5 PROJECT SPECIFIC QA/QC

At a minimum, the project-specific requirements will be inclusive of the items identified in Section 3.3 of the RFP. Woods Hole Group takes no exceptions with these requirements, including:

- Use of calibrated instrumentation with documentation.
- Adherence with SOPs (if applicable)
- Documentation and field notes
- QA/QC procedures for raw and processed data (described in Section 4.1.1)
- Early notification of problems and remedies
- Careful review of deliverables prior to submittal
- Permission for CDM to conduct onsite audits/inspections

3.0 FIELD STUDY (TASK 2)

3.1 TASK 2-1 – INSTALLATION OF H-ADCP IN CHEESEQUAKE INLET

Quantification of tidal exchange through the Cheesequake Creek inlet will be performed using a horizontal mounted acoustic Doppler current profiler (H-ADCP) deployed for a one month period. The data collection period will capture both spring and neap tides and a full month of dynamic tidal currents and backscatter data (suspended sediment). The H-ADCP will profile current velocity and direction across the channel and the temporal sediment flux. The exact bin resolution and sampling interval of the H-ADCPs will be discussed with the client prior to deployment.

Woods Hole Group plans to use the Sontek SL-500 current meter as the H-ADCP. The 500 kHz instrument will observe a cross-channel profile throughout the deployment period and, based upon the sampling scheme (e.g., time averaged), will capture a continuous time-series of velocity, direction, and acoustic backscatter. The SL-500 is powered by an internal battery and all data are stored on the instrument's non-volatile memory. Further information about the SL-500 can be found in the instrument manual.

The H-ADCP will be secured using appropriate mounting hardware to existing infrastructure (e.g., pilings) at the vertical mid-point of the water column. Randive has been contracted by WHG to install and recover the H-ADCP using a team of divers. If possible, the installation should occur at slack low tide to ensure the instrument remains submerged for the duration of the deployment, and to minimize the effect (if any) that tidal currents will have upon the dive team. Recovery by the Randive dive team will occur after a minimum period of one month. The proposed H-ADCP location is located on the southernmost free standing wood piling along the west bank of the inlet;

approximately 100 feet north of the Route 35 bridge (Figure 2). Alternate deployment locations will be employed only with client approval. It is anticipated that exact locations will be determined following a reconnaissance visit, and based on other potential factors such as physical setting (water depth at the piling), access, security, and desired data needs. The SL-500 has a vertical acoustic beam angle of 3.8 degrees; therefore, the instrument must be installed at a depth of at least 5.5 feet mean low water (MLW) to profile across the 165' channel. Woods Hole Group will work with the client to ensure the instrument is placed in a suitable and approved location prior to deployment.

Upon recovery on the instrument, data will be downloaded from the instrument and reviewed for data quality.

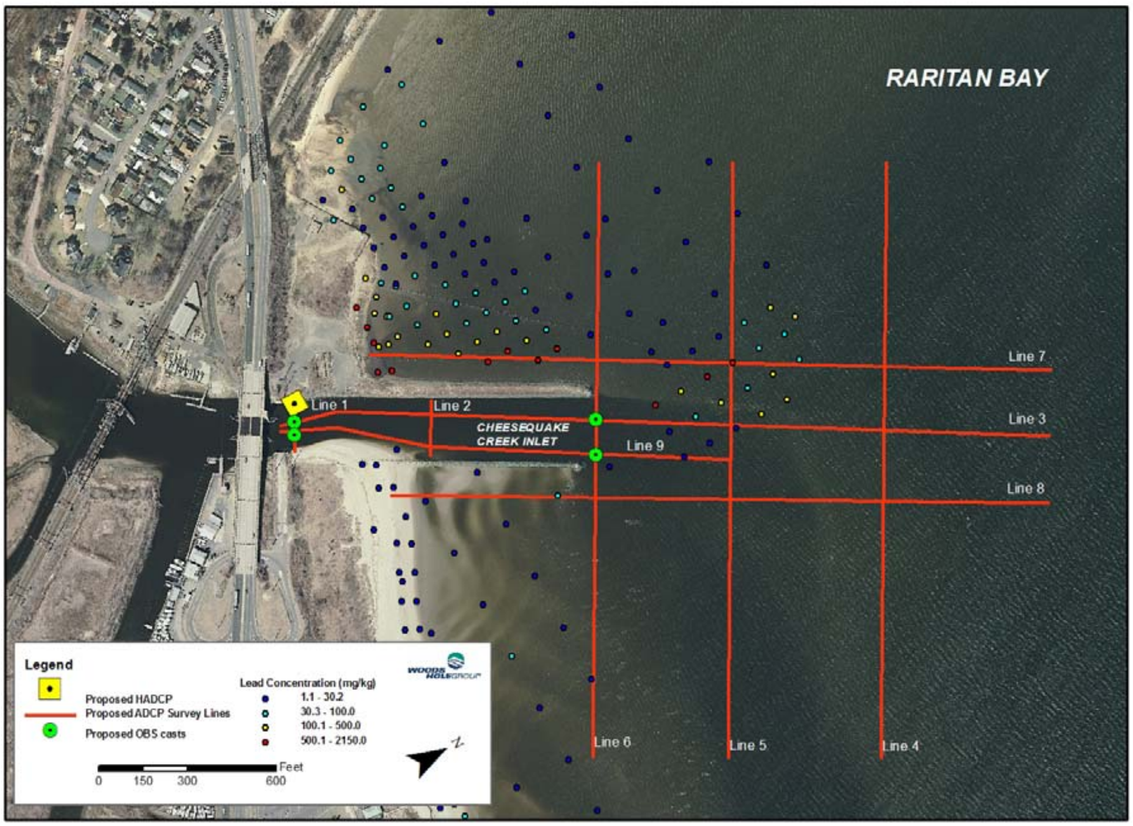

Figure 2. Proposed H-ADCP location (Task 2-1), tidal current survey lines (Task 2-2), and turbidity profiles (Task 2-2).

3.2 TASK 2-2 – 12.5-HOUR TIDAL CYCLE CURRENT SURVEY

During the deployment period for the H-ADCP in Cheesequake Inlet, the WHG field team will perform two vessel based current surveys in Cheesequake Inlet and the surrounding waters (Figure 2). One of the "ADCP surveys" will occur during a spring tide, while the other will occur during a neap tide to quantify the spatial distribution of currents in the inlet and surrounding waters during two different tidal stages. Each survey will take place over a 12.5 hour period to capture the complete tidal cycle (e.g., flood and ebb tidal currents). Based upon the proposed length of the nine survey lines (or transects) presented in Figure 2, a vessel survey speed of 3 knots (with some transit time between lines), it is estimated that the field crew will complete nine cycles of the survey area. One cycle is defined as the completion of all nine survey lines and the completion of water quality samples and OBS profiles (presented below).

Current and backscatter (suspended sediment) measurements will be made using the Sontek RiverSurveyor-M9 system. The RiverSurveyor M9 is a portable nine-beam acoustic Doppler profiler/discharge measurement system intended for use from moving boats and other floating platforms in shallow to medium depth channels. The RiverSurveyor will use an integrated RTK GPS sensor for navigation data (± 3 cm horizontal accuracy). Although data are stored on the instrument's non-volatile internal memory, Bluetooth telemetry will be used to transmit data back to a laptop on the survey vessel.

The RiverSurveyor will be deployed on a floating hydroboard tethered to the M/V Linda Ann, chartered from Randive. In order to assist the vessel captain with navigation of the survey lines, WHG will operate a second laptop computer running the HYPACK hydrographic software package.

Survey lines 2–8 will be performed by tethering the RiverSurveyor hydroboard to M/V Linda Ann. However, due to the narrow channel geometry and expected strong currents during peak flood and ebb tides, survey line 1 will be completed by tethering the RiverSurveyor to a temporary cableway used to tow the unit across the inlet channel (Figure 3). The cableway will only be suspended across the Cheesequake Inlet channel for the measurement of the survey line; upon completion of the survey line measurement, the cableway will be removed to allow for normal vessel traffic. The entire procedure of setting up the cableway, collecting the velocity measurement, and cableway removal is estimated to take approximately 10 minutes. The field crew will be cognizant of vessel traffic during this procedure, and will transmit a notice to mariners over VHF radio prior to setup and after removal of the cableway.

The combination of the H-ADCP and ADCP survey data will provide a more comprehensive temporal and spatial representation of the current and sediment flux in the Cheesequake Inlet. The H-ADCP will provide a longer-term record that will provide valuable temporal information, will the ADCP survey data will provide spatial coverage of potential variations in circulation dynamics and sediment flux.

3.2.1 OBS Turbidity Profiles

To assist in determining the suspended sediment load within the water column, optical backscatter sensor (OBS) turbidity measurements will be also obtained during each ADCP survey. A YSI 6920-V2 data sonde equipped with an OBS will be used for the turbidity water column profiles. Data will be stored internally, and downloaded to a YSI 650 handheld unit following each profile. Prior to use, the OBS sensor will be calibrated using solutions of known turbidity in order to develop a relationship between optical backscatter return and actual water turbidity in nephelometric turbidity units (NTUs). OBS turbidity profiles are proposed at four locations in the Cheesequake Inlet (Figure 2). The OBS data will be utilized, along with the water quality samples (see following section), to verify the backscatter measurements taken by the acoustic meters (H-ADCP and boat-based ADCP surveys).

3.2.2 Water Quality Samples

CDM personnel will be collecting surface water samples during both ADCP surveys (neap and spring tides). Samples will be collected at three depths (near the surface, in the middle of the water column, and near the bed) at a point adjacent to the H-ADCP. Samples will be collected at three separate intervals on each of the following tides: ebb spring tide, flood spring tide, ebb neap tide and flood neap tide. The samples will be analyzed for total suspended sediments (TSS), total metals, and dissolved metals. This sampling and analysis is further discussed in CDM's RI/FS work plan and QAPP.

The TSS results will be used to determine a relationship between actual suspended sediment load and: 1) turbidity quantified by the OBS, and 2) acoustic backscatter quantified by the H-ADCP.

In summary, a total of 6 water samples will be collected from one location over the course of each ADCP survey period.

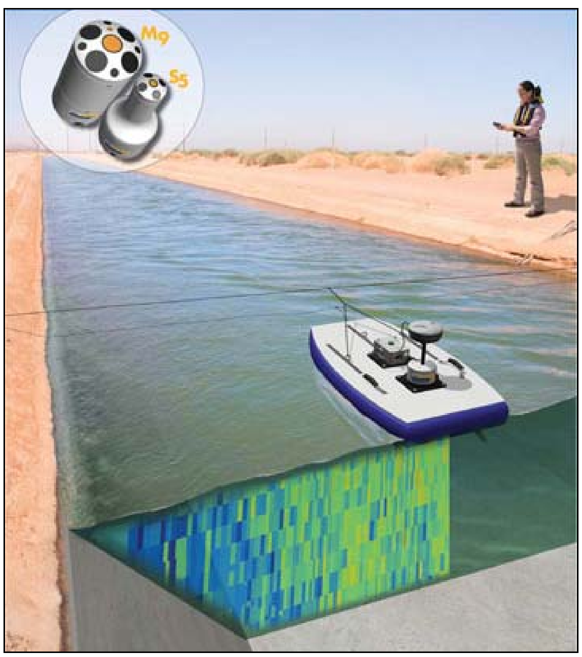

Figure 3. Proposed setup for tidal current survey line 1 using a cross-channel towing cable for the RiverSurveyor-M9.

3.3 TASK 2-3 – INSTALLATION OF BOTTOM-MOUNTED ACOUSTIC DOPPLER CURRENT METERS AT FOUR LOCATIONS

The field work proposed for Task 2-3 will require the successful deployment of four current and/or current and wave measurement systems. One instrument platform will be deployed at an offshore location northwest of Sandy Hook, NJ. The other three platforms will be deployed in the nearshore of Areas 1, 2, and 3. All four locations are depicted in

Figure 4 and described in Table 1. Table 1 provides a detailed description of the station ID, the proposed instrument type, geographic position, and estimated depth. All instruments will be deployed for a minimum of 30 days to ensure that a complete lunar tidal cycle is recorded. All instrument compasses will be calibrated on-site, prior to deployment.

All instrument deployments and recoveries will be performed by WHG field engineers and subcontractor Randive of Perth Amboy, NJ. Woods Hole Group will supervise Randive activities. Randive will provide a vessel to serve as the offshore work platform, and divers to deploy, secure, and recover the instrument platforms from the bottom. Following deployment of a platform, a geographic position will be recorded using a Differential Global Positioning System (DGPS) with a horizontal accuracy of 1 meter. All instrument platforms will be equipped with acoustic transponders (underwater locator beacons), which will assist the divers in locating the instrument platform during the recovery process.

The position for station O-1, the offshore waves and currents data collection location, was selected because it is adjacent to the position of Raritan Bay node in NYHOPS hydrodynamic model hosted by the Stevens Institute of Technology. At this location WHG will deploy a TRDI 1200 kHz Workhorse acoustic Doppler current profiler (ADCP) equipped with the Waves processing firmware. Woods Hole Group routinely uses the TRDI ADCP in successful current and wave data collection campaigns over a variety of coastal environments. The ADCP will be installed in a protective trawl resistant bottom mount (TRBM). The ADCP will continuously collect and record current profiles and surface wave data at set intervals over the course of the 30-day deployment. The TRBM containing the ADCP will be lowered to the bottom and deployed by divers. The divers will ensure the platform is resting horizontally on the bottom, and will secure the platform in place using helical screw anchors and chain.

The positions for stations N-1, N-2, and N-3, which are the three nearshore measurement systems, were selected based on the proximity to the known contaminant sources, and to provide a data collection point along each of the three shoreline reaches that make up the Raritan Bay Slag Superfund coastal system. WHG has proposed to deploy these measurement systems in the subtidal waters of Areas 1, 2, and 3. Due to the gentle slope of beach profile and the 4-5 foot tide range at these three sites, the instruments will be deployed at the outer edge of the designated study area in approximately 3 feet of water at mean lower low water (MLLW). The nearshore instruments will be mounted to a weighted fiberglass platform using stainless steel clamps. The platforms will be weighted with approximately 140 pounds of lead, and divers will secure to the sandy bottom using helical screw anchors and chain. After securing the platforms into the substrate, the instruments should rest approximately 6-12 inches above, and parallel to the bottom.

Two of the stations (N-1 and N-3) will be identically equipped with a Nortek 2 MHz Aquadopp High Resolution Profiler with a 90° head orientation. The 2 MHz Aquadopp with 90° head is the ideal instrument for collecting data in shallow coastal environments. The high frequency acoustic signal allows the instrument to collect water column profiles in small bin sizes with a negligible blanking distance, and the 90° head allows the instrument to be mounted horizontally along the bottom, enabling the user to maximize the amount of water column available for measurement.

Station N-2 will be equipped with a Sontek ADV-Ocean. The ADV-Ocean is a single point current meter that is a fully integrated, 3-axis (3D), ocean sensor system that includes a powerful data acquisition system, a high-resolution 5 MHz acoustic Doppler velocimeter, and a strain gage pressure sensor. The instrument measures velocities within 18 cm of the transducer faces. The Sontek ADV-Ocean and wave spectra software package uses the proven PUV method for directional wave measurement. This method requires accurate measurement of pressure (P) and horizontal velocities (UV) at data rates high enough to resolve wave energy.

Upon recovery of the four platforms and instrumentation, data will be downloaded from the instruments and begin a rigorous QA/QC data quality and analysis process.

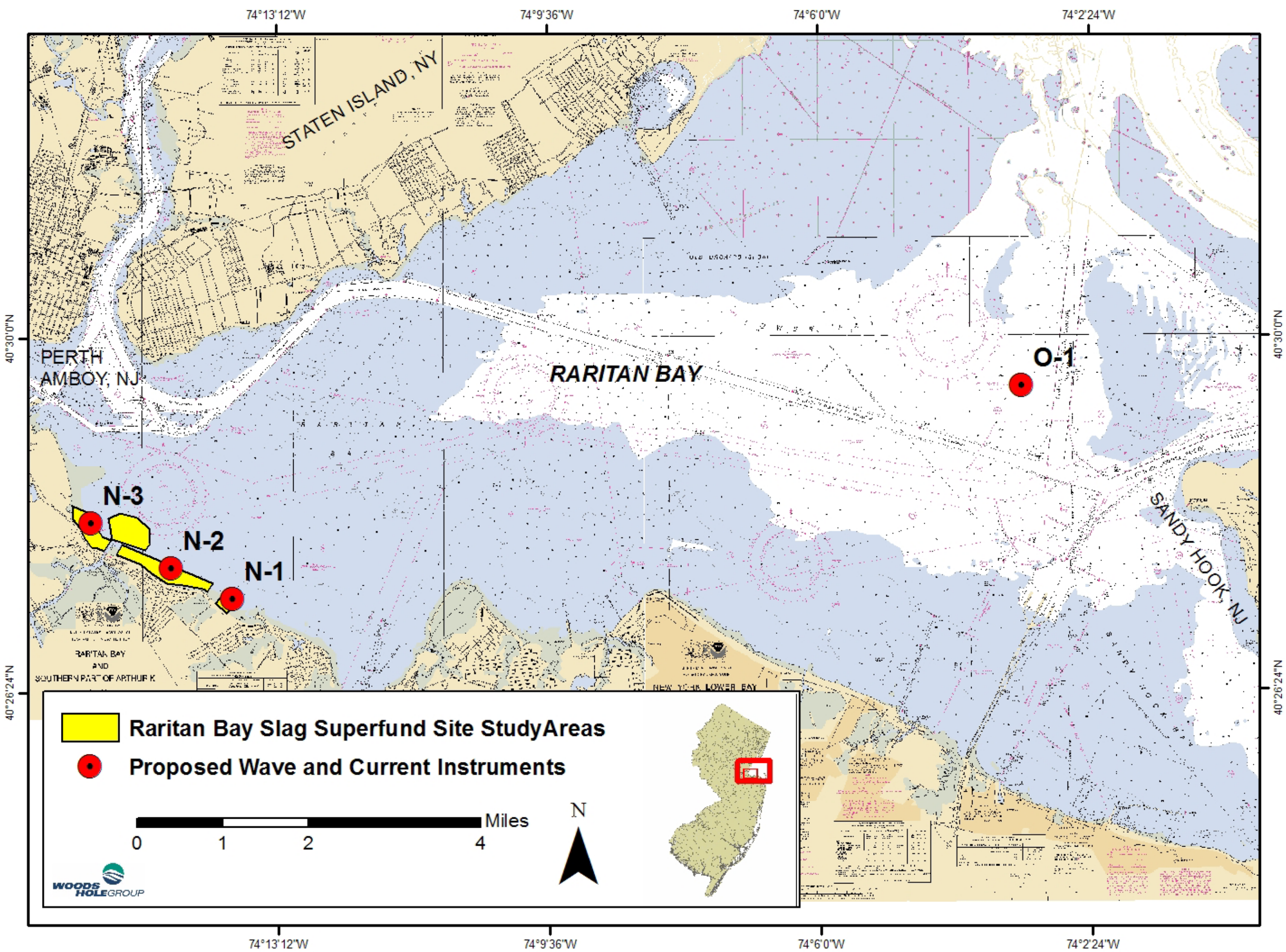

Figure 4. Proposed locations for bottom-mounted acoustic Doppler current and wave measurement instruments (Task 2-3).

Table 1. Proposed Instrument Locations for offshore bottom-mounted acoustic Doppler current and wave measurement instruments (Task 2-3).

Station ID	Location Description	Proposed Instrument	Longitude	Latitude	Depth (feet, MLLW)
O-1	Offshore Waves and Currents	TRDI 1200 kHz Workhorse ADCP with Waves and Sonardyne or Benthos UAT-376 transponders	74° 3.3099	40° 29.4998	24
N-1	Area 1 Currents	Nortek 2 MHz Aquadopp ADP with 90° head and Sonardyne or Benthos UAT-376 transponders	74° 13.8032	40° 27.3535	3
N2	Area 2 Waves and Currents	Sontek 5 MHz ADV Ocean and Sonardyne or Benthos UAT-376 transponders	74° 14.6188	40° 27.6682	3
N-3	Area 3 Currents	Nortek 2 MHz Aquadopp ADP with 90° head and Sonardyne or Benthos UAT-376 transponders	74° 15.6841	40° 28.1202	3

3.4 FIELD STUDY SCHEDULE

The schedule proposed below is provided to guide the organization of the field study; the schedule is subject to change in response to weather or other factors. However, tidal current surveys must be performed once during a neap tide, and once during a spring tide, which only occur at specific times. The predicted tide levels for the site are presented in Figure 5 to assist with planning if changes to the proposed work plan schedule are required.

- November 14, 2010
  Travel Day

- November 15, 2010
  Task 2-1 – H-ADCP Installation
  06:43 – sunrise
  09:12 – low tide
  14:58 – high tide
  16:39 – sunset

- November 16, 2010
  Task 2-2 – 12.5-hour NEAP tidal cycle current survey
  05:00 – start mobilization
  06:00 – start survey
  06:44 – sunrise
  16:38 – sunset
  18:30 – end survey
  19:00 – demobilization complete

- November 17, 2010
  Task 2-3 – Installation of Bottom-Mounted Acoustic Doppler Current Meters at Four Offshore Locations
  06:00 – mobilize Randive M/V Becky Ann
  06:45 – sunrise
  07:00 – depart dock, transit to offshore deployment location
  08:00 – arrive at offshore deployment location
  10:00 – depart offshore location for deployment locations at Areas 1, 2, 3
  10:52 – low tide
  15:00 – deployments complete
  16:00 – return to dock, demobilize vessel.
  16:38 – sunset
  16:42 – high tide

- November 18, 2010
  Travel Day

- November 19, 2010
  Weather Delay

- December 5, 2010
  Travel Day

- December 6, 2010
  Task 2-2 – 12.5-hour SPRING tidal cycle current survey
  05:00 – start mobilization
  06:00 – start survey
  07:05 – sunrise
  16:30 – sunset
  18:30 – end survey
  19:00 – demobilization complete

- December 7, 2010
  Travel Day

- December 15, 2010
  Travel Day

- December 16, 2010
  Task 2-1 – H-ADCP Recovery
  Task 2-3 – Recovery of Bottom-Mounted Acoustic Doppler Current Meters at Four Offshore Locations
  06:00 – mobilize Randive M/V Becky Ann
  07:13 – sunrise
  07:00 – depart dock, transit to offshore deployment location
  08:00 – arrive at offshore deployment location
  10:00 – depart offshore location for deployment locations at Areas 1, 2, 3
  10:17 – low tide
  15:00 – deployments complete
  15:56 – high tide
  16:00 – return to dock, demobilize vessel.
  16:31 – sunset

- December 17, 2010
  Travel Day

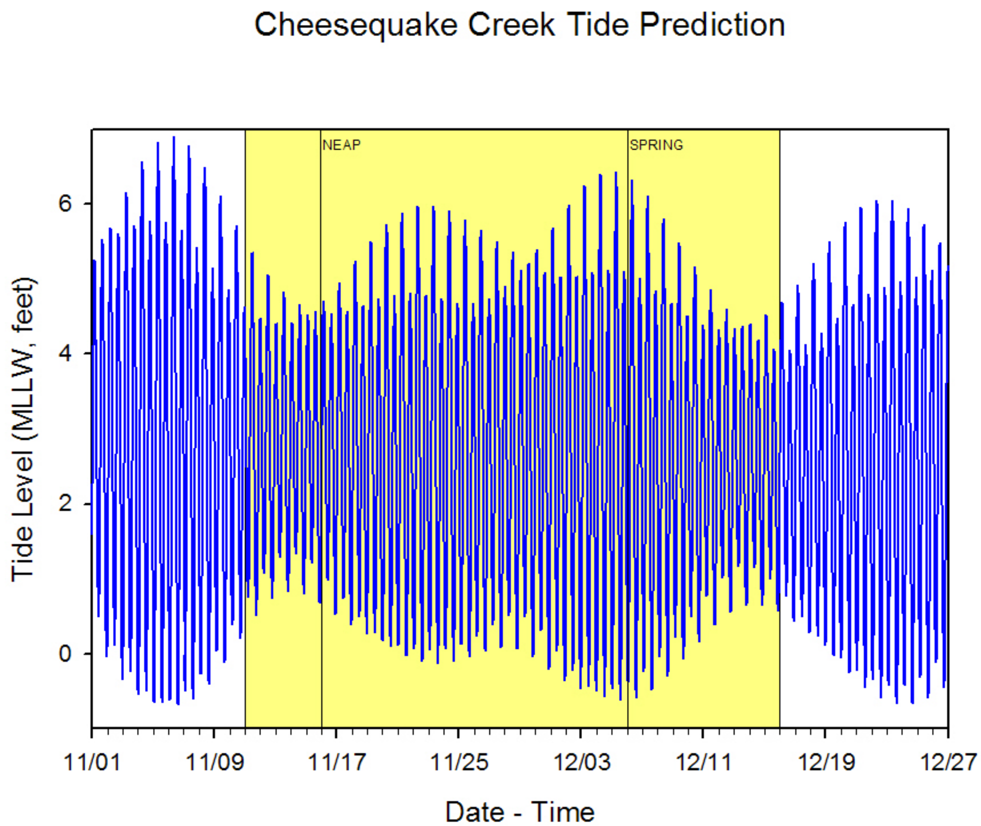

Figure 5. **Tide prediction for Cheesequake Creek, Laurence Harbor, NJ. The yellow box highlights the proposed deployment period for instruments. The proposed neap (11/16) and spring (12/06) current survey events are indicated by the black lines.**

4.0 QUANTITATIVE PROCESS CHARACTERIZATION (TASK 3)

4.1 FIELD STUDY DATA ANALYSIS

4.1.1 Data Quality Control

Upon instrument recovery, data will be immediately recovered or downloaded from the non-volatile memory of all instruments and backed up to two independent forms of media (e.g., laptop computer, memory stick, CD). In the office, raw data files will be processed using the respective instrument manufacturer's software to convert the data file format from binary to ascii based formats in preparation for subsequent analysis. Original data files will be saved on the company's secure servers.

The following QA/QC procedures, adapted from the USGS Woods Hole Science Center, are followed by Woods Hole Group to ensure data quality for use in analysis:

- Instrument identifications, sampling configuration, calibrations, locations, and timing marks are checked with mooring logs and, if necessary, personnel that deployed the instruments.
- Documented procedures and software are used to decode and calibrate data, to derive secondary variables (statistics, salinity, etc.), and to convert data formats.
- The time base of the data is checked for consistency with records of instrument deployment and recovery; data are checked for time gaps. Data recorded out-of-water or during instrument placement or recovery are removed.
- All acoustic data will be reviewed for data quality by inspection of acoustic metadata, to ensure that a transducer's data quality in not bad (e.g., obstructed transducer). The maximum "good" beam solution will be used in all cases.
- Data sets are examined by scanning statistics and plots of raw data for outliers, sensor or recorder malfunction or impairment, or other artifacts. Causes of sensor and recorder malfunctions are determined to the extent possible in collaboration with the scientific and technical staff that prepared and deployed the instruments.
- Documented procedures and software are used to replace erroneous values with interpolations or pad values, as appropriate. Where possible, fixes for known errors are implemented and documented.
- Data are compared with other data sets to verify time base, calibrations, and sensor function.
- All data-processing steps are documented and recorded, as are a record of any data values that were edited, replaced or deleted, the reasons for these actions, and the algorithms used for interpolation.

4.1.2 H-ADCP Data

H-ADCP current data will be post-processed and provided in three specific formats:

- Tabular data files for ADCP data bins containing date and time of observation, easting and northing coordinate of the observation, easting and northing velocity, and current speed and direction.
- Color contoured data plots showing the upstream/downstream and cross stream velocities at representative times during a typical tidal cycle and for any unique events that may occur during the month deployment (e.g., rainfall event, storm surge event, etc.).
- Vectorized data with data points output at least every 25 feet along the cross-inlet profile. Data will be provided both in tabular format, as well as aerial view plots presenting vectors for representative time periods throughout the deployment.

The H-ADCP data, coupled with the tidal survey data, will also be analyzed to calculate the volumetric water flux of the complete tidal inlet cross-section, and backscatter data will be analyzed for suspended sediment flux. Backscatter data will be correlated to OBS observations, boat-based ADCP backscatter data, and water sampling (to be collected by CDM) to verify and calibrate the backscatter data observations. Water level data will be corrected for atmospheric pressure, converted to water surface elevation using the hydrostatic relationship based on the density of water at the site, and adjusted to a vertical datum (if a surveyed benchmark is provided by CDM).

4.1.3 Tidal Cycle Current Survey Data

Following the data recovery efforts, all data will be post-processed and QA/QC'd to ensure accuracy. Boat-based ADCP data will be post-processed and provided in three specific formats, similar to the H-ADCP data:

- Tabular data files for all ADCP data bins containing date and time of observation, easting and northing coordinate of the observation, depth of the observation, easting and northing velocity, and current speed and direction.
- Color contoured data plots showing the upstream/downstream and cross stream velocities for each transect throughout the tidal cycle.
- Depth-averaged vectorized data, with data points output at least every 25 feet along the transect line. Depth-averaged data will be provided both in tabular format, as well as aerial view plots presenting vectors for each transect throughout the tidal cycle.

OBS data will be post-processed, plotted, and presented in both tabular and graphical format. The data will also be used with the collected ADCP current data to determine potential sediment flux from the ADCP backscatter results. The report will describe the correlation and the sediment flux calculations.

4.1.4 Nearshore and Offshore Currents and Waves

Following the data recovery efforts, all data from the bottom-mounted current and wave instruments will be post-processed and QA/QC'd to ensure accuracy. Data will be analyzed to produce:

- Tabular data files for all ADCP data bins containing date and time of observation, depth of the observation, current speed and direction, and wave height, period (if applicable).
- Color contoured, depth varied, time-series plots of current velocity.
- Plots of wave spectral energy
- Rose and/or polar plots of wave direction

These data will provide the basis for a quantitative wave and sediment transport evaluation. Specifically, the measurement of offshore wave data, which will verify the existing NYHOPS wave model, will provide input conditions for local wave transformation calculations, and be used to characterize the wave-induced current driving sediment transport at the shoreline.

4.2 CONSOLIDATE/ANALYZE EXISTING DATA AND MODELS

In addition to the data collected as a part of Task 2, the scope of work for Objective 1 consists of evaluating the utility of existing data observations and hindcast and forecasting model results to characterize the hydrodynamics and sediment dynamics in the four study areas of the Raritan Bay Slag Superfund Site. To supplement the data collection efforts (Task 2), Woods Hole Group plans to obtain and utilize publicly available sources including field observations and fully developed hydrodynamic models to assist in the characterization of the hydrodynamics within the study area. It is expected that the existing data observations, as well as detailed existing model results, can provide additional important information regarding the hydrodynamics within the vicinity of the Raritan Bay Slag Superfund Site facility. The analysis of the existing data will be focused on supplementing the data collection and analysis efforts presented herein by: (1) identifying the dominant hydrodynamics and current patterns within the four critical study areas; (2) characterizing the water flux within the four critical study areas; (3) determining the net sediment transport within the four critical study areas, including the maximum sediment excursion; (4) determining the influence of extreme events (storms) on the water and sediment flux; (5) identifying potential areas of erosion and accretion in the area; and (6) providing recommended sampling locations, including areas that may not have been sampled previously. The data and models intended for analysis include, but are not limited to, the following:

- National Oceanographic and Atmospheric Administration (NOAA) data obtained from the National Ocean Service (NOS) Office of Coast Survey Hydrographic Survey Geophysical Data System (GEODAS)
- NOAA's Port of New York and New Jersey Operational Forecast System (NYOFS)
- New York Harbor Observing and Prediction System (NYHOPS), developed and maintained by the Stevens Institute of Technology Center for Maritime Systems
- NOAA/NOS PORTS station SDHN4 located at Sandy Hook
- United States Army Corps of Engineers, Coastal Hydraulics Laboratory, Wave Observation Station in Raritan Bay (NJ002)
- USGS water level observations at Keansburg, NJ

- MUUCI water level, salinity, and water quality parameters at Keyport Yacht Club, NJ
- Data from the HYHOPS observational system
- Mid-Atlantic Regional Coastal Ocean Observation System (MARCOOS) HF Radar surface current observations
- New Jersey Toxics Reduction Workplan (Chant, 2006)

Of specific interest are the NYHOPS and NYOFS models that provide calibrated simulations of water levels, currents, waves, and other physical processes within Raritan Bay. Both NOAA's Port of New York and New Jersey Operational Forecast System (NYOFS) and the New York Harbor Observing and Prediction System (NYHOPS), developed and maintained by the Stevens Institute of Technology Center for Maritime Systems, will be extensively evaluated and used to obtain data related to the hydrodynamics and tidal currents within Raritan Bay and in the direct vicinity of the Slag Superfund Site and Cheesequake Creek.

The NYOFS is driven by a three-dimensional hydrodynamic model that uses real-time water level and wind data along with other inputs to predict water levels and currents at thousands of locations within the NY/NJ harbor system. Archives of the predicted tidal currents will be used to quantify average ebb and flood tidal conditions, as well as spring/neap tides throughout the project area. Figure 6 shows the NYOFS coarse grid model output (a more resolved fine grid, which provides higher resolution of current results is also available and data from the higher resolution grid will be obtained for this study) for conditions on October 21, 2009 at 1800 hours.

To supplement the NYOFS model output, additional data pertaining to the hydrodynamics will be obtained from NYHOPS. NYHOPS is an open-access network of distributed sensors and linked computer estuarine and coastal ocean forecasting models. The system is designed to allow for the real-time assessment of ocean, weather, and environmental conditions throughout the New York Harbor region, and forecast of conditions in the near and long-term. The modeling system consists of a three-dimensional circulation model and a wave model based on the Estuarine Coastal and Ocean Model (ECOMSED), a derivative of the Princeton Ocean Model (POM) developed by Blumberg and Mellor (1987). The NYHOPS implementation of ECOMSED/POM is based on the work of Blumberg et al. (1999). The spatial extent of the NYHOPS domain incorporates the core area of NY/NJ Harbor and extends beyond to include the Hudson River Estuary up to the Troy Dam, all of Long Island Sound, and the New York Bight out to the continental shelf (Figure 7). Figure 8 shows a closer view of representative NYHOPS model results in the Raritan Bay region (snapshot shown for January 8, 2010 at 1600 hours).

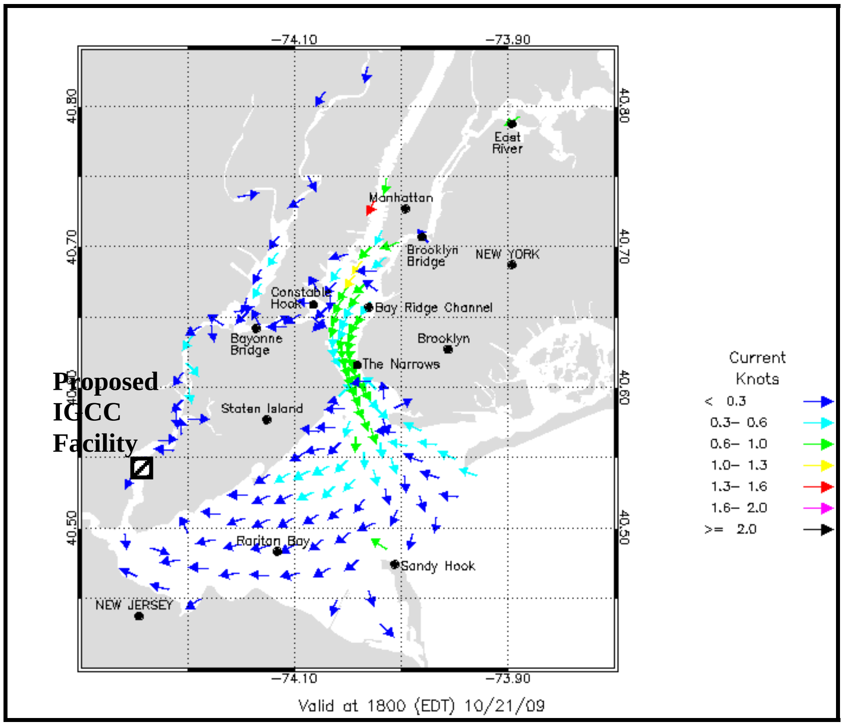

Figure 6. **Example of NOAA's Port of New York and New Jersey Operational Forecast System Model Output for the current regime on October 21, 2009 at 1800 hours.**

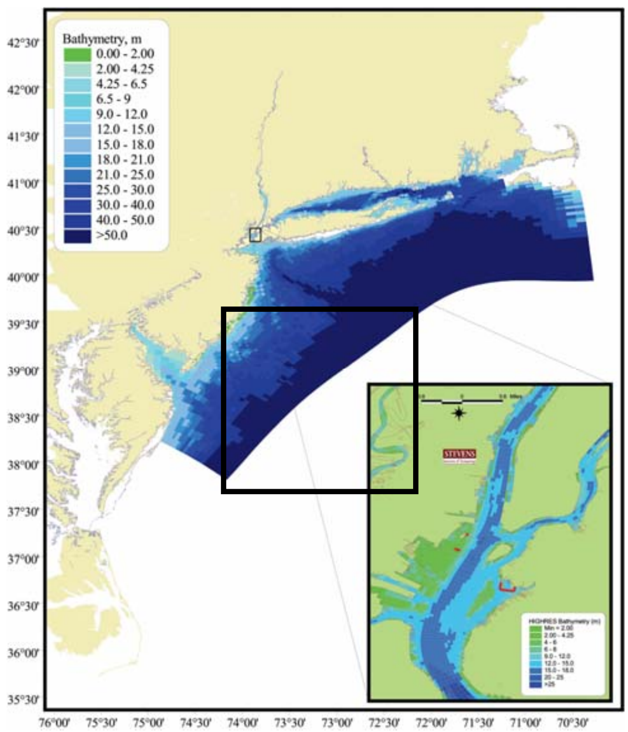

Figure 7. **Overall model domain of Stevens Institute New York Harbor Observing and Prediction System (NYHOPS).**

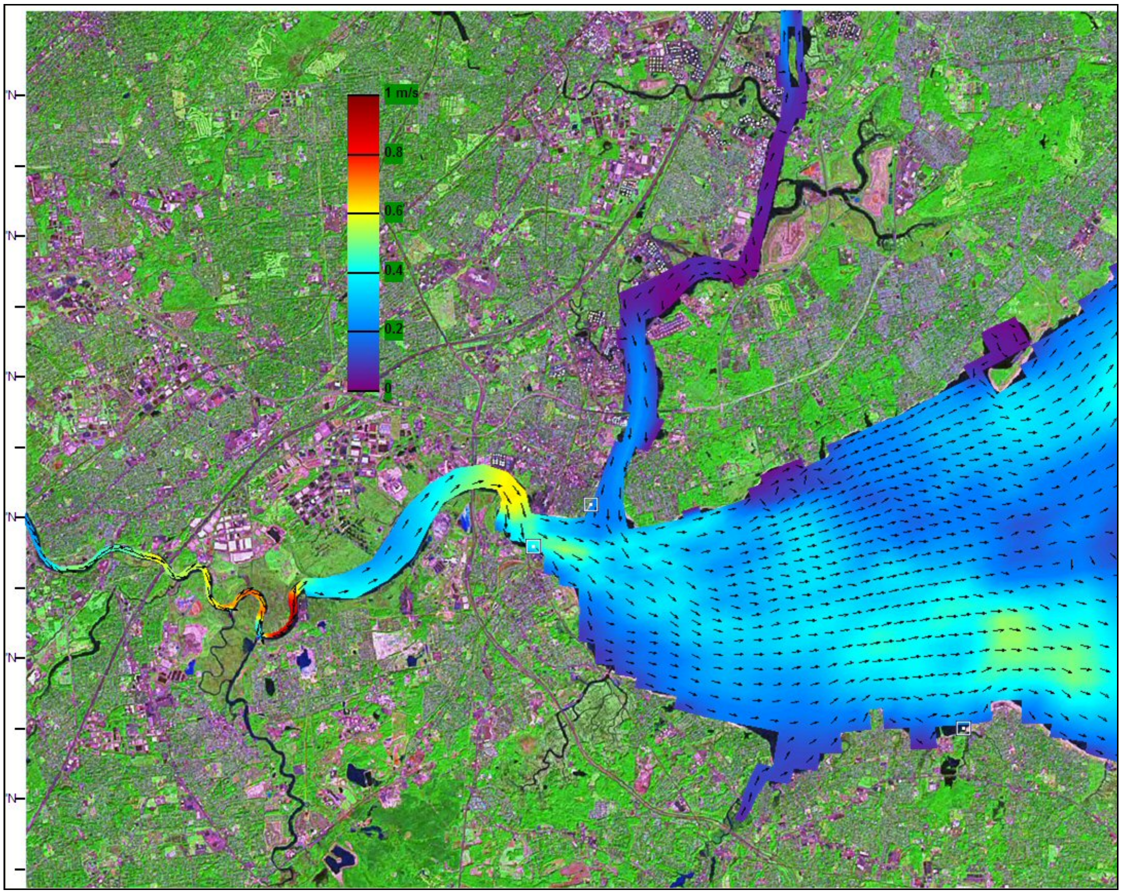

Figure 8. **New York Harbor Observing and Prediction System (NYHOPS) model results for the Raritan Bay region on January 8, 2009 at 1600 hours.**

In addition, Woods Hole Group will research historical studies including any shorter-term field data collected within Raritan Bay. It is anticipated that the 2006 study performed as part of the New Jersey Toxics Reduction Workplan (Chant, 2006) will provide useful information regarding the relevant environmental conditions in Raritan Bay (i.e. water depth and hydrodynamics). The relevant hydrodynamic information will be gathered, analyzed, and interpreted to develop a summary of the physical processes that may transport water-borne and sediment-borne contaminants. The hydrodynamic analysis will also identify the potential transport pathways of the dissolved metals in the water currents at the site. Following the analysis and interpretation of the hydrodynamics in the near-field region of the Raritan Bay Slag Superfund Site, the potential transport of the sorbed metals in the sediment will also be analyzed.

4.3 WAVE AND SEDIMENT TRANSPORT CALCULATIONS

4.3.1 Wave Transformation Calculations

Woods Hole Group believes that sediment transport along a majority of the Raritan Bay Slag Superfund Site is a wave-dominated process, especially in the vicinity of the seawall. As such, the goal of the analysis is to provide a physically-based representation of alongshore currents and sediment transport driven by not only the tidal currents, but also the breaking waves in the surf zone.

The impact of waves in the nearshore environment, specifically on shorelines that have anthropogenic influences, significant coastal structures, are highly populated, serve significant recreational and/or economic benefits, or have contaminated sediment (such as the shoreline along Laurence Harbor, NJ), is one of the key reasons to understand wave propagation, transformations, and predictions for site-specific areas. The impact of waves on nearshore processes and shoreline change is highly dependent on the offshore wave climate and the transformation of waves propagating to the shoreline. Subsequently, as the waves interact with the coastline, the wave-induced currents are a major component of sediment transport and shoreline change. Therefore, a key component of understanding areas of erosion and accretion along the shoreline is determining the nature of the wave field both offshore and in the nearshore region.

Quantitative characterization of waves is required to simulate refraction, diffraction, shoaling and breaking of waves occurring in the region. These nearshore wave transformation processes determine the effects waves will have on the shoreline. For example, wave refraction and diffraction processes produce an uneven distribution of wave energy along the coast and affect sediment transport in the region. Wave energy may end up being distributed unevenly along the coast; therefore, resulting in areas of increased erosion ("hot spots") or creating variations in sediment transport pathways along the length of the coast. The type of analysis described herein allows for quantitative predictions of these wave processes.

A regional, spectral wave climate characterization will be utilized to assess the nearshore wave prediction. A spectral approach marks a significant improvement from the more traditional monochromatic wave calculations. The spectral approach makes it possible to calculate the actual complexities of the sea surface, which is composed of a large variety of waves moving in different directions and with different frequencies, phases, and heights. As part of the quantitative wave climate characterization, Woods Hole Group will incorporate topographic and bathymetric data collected by CDM and its subcontractors. Woods Hole Group will also utilize wind data already obtained for the region (existing data) and proven methodologies already established for correlating input winds with observed waves and/or NYHOPS modeled waves. Woods Hole Group will evaluate average annual wave directional approaches and extreme storms (e.g., 100-year return period event). The effects of sea-level rise on the wave climate will also be examined. Numerical wave calculations provide a tool to help understand the effect on the shoreline from changes in wave height, wave direction, areas of increased energy concentration, structural design configurations, sediment transport, and ultimately proper shoreline management.

4.3.2 Sediment Transport Calculations

In addition to the quantitative wave characterization, WHG will characterize sediment transport utilizing output from the wave transformation calculations and tidal current observations to gain an understanding of the average and storm-induced rates of sediment transport along the shoreline. Quantitative estimates of sediment transport will be developed utilizing the topographic and bathymetric data collected by CDM, as well as the substrate sediment grain size data (also collected by CDM). The conceptual site model will then be used to simulate the average annual directional wave conditions, the representative yearlong time span, and the previously identified storm conditions. The specific objective is to obtain physically-based estimates of the alongshore sediment flux integrated across the surf zone. The analysis will develop both a combined hydrodynamic component, and a sediment flux component that will produce the sediment dynamics at work in the vicinity of the Site.

Wave action constantly moves sand in the longshore direction due to wave-induced currents created by breaking waves. These wave-induced currents are ultimately what moves sand and material around on the beach. As such, the wave characterization provides the key input into the sediment transport calculations. From the wave characterization results, wave-induced currents, and subsequently, sediment transport fluxes (rates and directions of sand movement) will be developed. These fluxes indicate the net sediment transport potential along the shoreline. In addition, areas of convergence and divergence (the patterns of erosion and accretion) will be determined to identify potential spatial variations in the sand movement, and in this case contaminated sediment movement. To this end, the existing movement of sediment will be identified, and subsequently the transport processes and pathways associated with the contaminated materials.

This approach has been regularly used by Woods Hole Group, including in the presence of coastal structures (e.g., groins, seawalls, jetties), to identify the movement of sediment in the nearshore coastal zone. The approach has been used in significant court case of sediment transport determination, critical shoreline restoration projects, and to design a wide array of coastal mitigation solutions (e.g., beach nourishment, offshore breakwaters, seawall reconfigurations/reconstructions, coastal groins and jetties, etc.). This option will produce results of the local wave and sediment transport processes, supported by data that accurately characterize the existing conditions at the site under a range of conditions.

5.0 REPORTING (TASK 4)

A draft data summary and analysis report will be submitted to CDM. The draft report will incorporate a summary of the field study efforts; this includes the results of the H-ADCP data collection, the results of the boat-based ADCP surveys, results of the OBS casts, and the nearshore and offshore currents and wave measurement. The analysis section will provide calculations of the tidal exchange, and both the water and sediment flux, into and out of the Cheesequake Creek Inlet. In addition, the report will provide information on the currents and formation of the ebb flood shoal, and the overall importance, or lack thereof, of the tidal currents in the vicinity of the inlet and associated jetty.

A section of the report will summarize the existing data analysis. This will describe the data obtained, sources utilized, work completed, the results of the analysis, and recommendations for additional sediment sampling (if needed). The report will provide details on both the transport of dissolved metals in the surface water currents, and the transport of sorbed metals in the sediments.

The draft report will contain a summary of quantitative process characterization for the Site. The section will summarize existing shoreline conditions, results of the quantitative characterization effort, pathways and rates of sediment transport, zones of sediment convergence and divergence, areas of potential concern for contamination, and recommendations for additional sampling (if needed). The methodology for all numerical calculations to simulate waves and sediment transport in the project area will be described. The report will detail assumptions inherent to the analysis, and will include information pertaining to the calculation inputs and boundary conditions, grid development, and validation.

The draft report will provide CDM an opportunity to review the results of the study and to offer comments on the study findings and the presentation of the study findings. A conference call will be conducted after CDM has reviewed the draft report for discussion and to provide comments. A final report containing changes or additions made to the draft report after CDM and other project partner comments will be completed after receipt of all comments from CDM. An appendix summarizing the comments may also be included, if appropriate. Woods Hole Group will provide CDM with 4 printed copies of the final report, as well as an electronic copy of the report on CD and all processed field study data.

6.0 REFERENCES

CDM. 2010. Statement of Work, in "Request for Proposal for Currents and Sediment Dynamics Studies for the Raritan Bay Slag Superfund Site, Old Bridge and Sayreville, New Jersey". Solicitation No. RFP-6402-018-004-CS. August 2010. CDM Federal Programs Corporation, 14420 Albemarle Point Place, Suite 210, Chantilly, VA 20151.

WHG. 2010–in progress. Accident Prevention Plan for the Currents and Sediment Dynamics Studies for the Raritan Bay Slag Superfund Site, Old Bridge and Sayreville, New Jersey.